Memorandum

To: Al Frechette, Scott County

From: Ray W. Wuolo, P.E., P.G.

Subject: Results of Independent Groundwater Flow Modeling for the Jordan Aggregate EAW Evaluation

Date: March 31, 2011

Project: 23701010.00

The following is our assessment of potential groundwater impacts from the proposed Jordan Aggregates Sand and Gravel Mine, as described in the EAW for the project. As instructed by the County, we modified an existing MODFLOW groundwater flow model of the area, included local detail and grid refinement, and performed independent simulations of the proposed project. Our primary focus was to evaluate the following:

1. What are the likely groundwater flow paths from the project (particularly the proposed mine pit) and what are the likely groundwater travel times?
2. Are any downgradient wells likely to be impacted in terms of quality or quantity from the proposed project?
3. After a flood, when the pit would likely be filled with Sand Creek water, how would groundwater flow patterns change and where would the flood water in the pit migrate to?
4. Would the City of Jordan's municipal wells be impacted by the project?
5. Would Sand Creek be impacted by the project?
6. Would water from the project site migrate down into the underlying Franconia Formation?

Groundwater Flow Model

The Metro Model II was used as the basis for developing a local, detailed MODFLOW model of the project area. The Metro Model II was developed in 2009 by Barr Engineering Company for the Metropolitan Council and underwent extensive model calibration, verification, and third-party peer review. This model includes all major surficial and bedrock aquifers in the Seven County metropolitan area. It is currently being used extensively by the Metropolitan Council to address numerous regional and local groundwater issues.

For this evaluation, a local-scale model, covering a large portion of Scott County, was constructed from the Metro Model using a process known as Telescoping Mesh Refinement (TMR). By constructing a local-scale model, much greater levels of detail and computational accuracy can be attained. The Metro Model grid was substantially refined throughout the TMR model domain and much greater grid refinement was designed for the project area. In addition to grid refinement, Sand Creek's boundary conditions (River Package cells) were substantially detailed. Geologic conditions, such as contacts of bedrock units, were checked in the refined model against well-log data from local wells in the County Well Index. Pumping rates for the SCALES well was also checked against the DNR's SWUDS database for appropriations pumping and daily average pumping rates were computed from these data. The pumping rate for the well at the Juvenile Alternative Facility is unknown but was assumed to pump at an average rate of 10 gallons per minute.

The model also underwent additional calibration to County Well Index target values and to water-level data reported for monitoring wells constructed for this project. The only adjustment made to the model was to increase the hydraulic conductivity value of the surficial sand and gravel from 28 ft/day (the calibrated Metro Model value) to 287 ft/day. Other factors, such as effective porosity and storage parameters were also checked for appropriateness.

Steady-State Groundwater Flow Model Simulations

The local, calibrated groundwater flow model was used to evaluate pre-project (i.e. "current" or "base") conditions and steady-state groundwater flow conditions with the mine pit at its full extent and the project well pumping at 200 gpm. Evapotranspiration from the pit was simulated, as were the variations in proposed pit bathymetry. Simulations of water-table elevations, groundwater flow paths, and groundwater time-of-travel from the pit are shown on Figure 1.

Under current conditions, the average groundwater velocity flowing downgradient of the pit area is approximately 1,880 feet/day (using an effective porosity of 0.2 and a hydraulic conductivity value of 287 ft/day). Only one well is identified as being downgradient of the pit area for existing conditions – the Robling Well (this well is not shown on Figure 1 but is assumed by McCain and Associated to be located approximately 500 feet NW of the site and screened at a depth of 105 feet).

With the pit in place (but the mine well not pumping), groundwater flow patterns and time-of-travel is predicted by the model to be altered. With the pit open and the mine production well not pumping, downgradient groundwater flow velocities are predicted to range from 1,620 feet/year to 2,750 feet/year. In addition to the Robling well, wells that are predicted to be downgradient of the Pit and within a 1-year time-of-travel are: Schenck well; the SCALES well, and Wayne well. The number of wells that receive water from the pit area expands with the pit in place because of the effect that the pit has on hydraulic gradients (flattening out the gradient across the pit footprint and thereby changing flow directions).

Simulation of the Effects of Pit Flooding

One of the reasons that Scott County wished to use MODFLOW to evaluate this project was that MODFLOW is capable of simulating transient groundwater flow. The capability of simulating transient flow allows for the evaluation of temporary flooding of the pit (due to flooding from the Sand Creek), followed by a dissipation in pit water levels and the migration of flood water from the pit into the aquifer.

For this simulation, the pit was assumed to be flooded to an elevation of 732 feet. The proposed mine well is not pumping. The pit was then allowed to dissipate the flood waters over a 5-year simulation period (although water levels returned to pre-flood conditions within about 2 weeks after flooding). The solute transport model MT3D was used to simulate the movement of the pit flood water out into the aquifer over the 5-year period. MT3D, coupled with MODFLOW, simulated not only horizontal migration of this water but vertical migration, as well. "Snapshots" of the simulated percent of flood water in the aquifer are shown on Figure 2 for 1 month, 2 months, 3 months, 6 months, 1 year and 2 years following flooding. If, for example, a non-reactive constituent (such as nitrate) were to have a concentration of 10 mg/L in the flood water, the concentrations in the groundwater would be predicted to be 8 mg/L at the 80 percent contour, 6 mg/L at the 60 percent contour and so on.

As Figure 2 shows, the floodwater "plume" migrates with groundwater flow to the northwest and as does so, it disperses (similar to dilutes) with the unaffected aquifer water. The concentrations depicted in Figure 2 are for a depth of 0 to about 30 feet below the water table. Concentrations deeper in the sand-and-gravel aquifer are somewhat less than those shown for this shallow zone. None of the flood water was found to reach the underlying bedrock (St. Lawrence and Franconia Formations).

The SCALES well will be affected by flood water, according to this simulation, but is not predicted to receive a full concentration of flood water. The Robling, another well identified by McCain and

Associates and the Wayne well (located near the northwest corner of the property), and the Schenck well are predicted to be affected by migrating flood waters. Whether or not the flood waters would result in degradation of water quality at these wells is unknown and would depend on the water chemistry of the flood water.

As a point of reference, the half-life of coliform bacteria in a fine to coarse sand is about 10 to 40 days. Coliform bacteria would likely decay below its half-life before reaching any of the downgradient wells. Other pathogens may not decay.

Simulations of Drawdown on Nearby Wells and Sand Creek

The model was also used to evaluate the effects of the project on the water levels of nearby wells and on the base flow of Sand Creek (which is a losing stream along this reach).

The model simulations indicate only small changes in groundwater levels at the nearby wells – not enough to cause any noticeable reduction in well capacity or yield. The model did not indicate that there would be any adverse effects on nearby municipal wells, including wells used by Jordan for water supply.

Under the base (pre-project) conditions, the model predicts that Sand Creek is a losing stream along this reach – losing approximately 0.2 cfs. With the pit in place and the well pumping, the same reach of Sand Creek is predicted to lose an additional 0.08 cfs. This takes into account the effects of flattening out the water table, caused by the excavation of the mine pit and the formation of a mine-pit pond that is the surface expression of the water table. Typical stream flows in Sand Creek between Jordan and Lynnville Drive are in the range of 1.1 to 1.8 cfs. Therefore, the additional loss of 0.08 cfs equates to approximately 4.5 to 7 percent of stream flow.

Conclusions

Based on this modeling evaluation, the following are concluded concerning the proposed project's impact on groundwater:

1. Under existing conditions, groundwater from the project area flows to the northwest at an average rate of approximately 1,880 feet/year, assuming an effective porosity of 0.2 and an average hydraulic conductivity value of 287 ft/day. There appears to be one well (the Robling well) that is downgradient of the site under existing conditions.

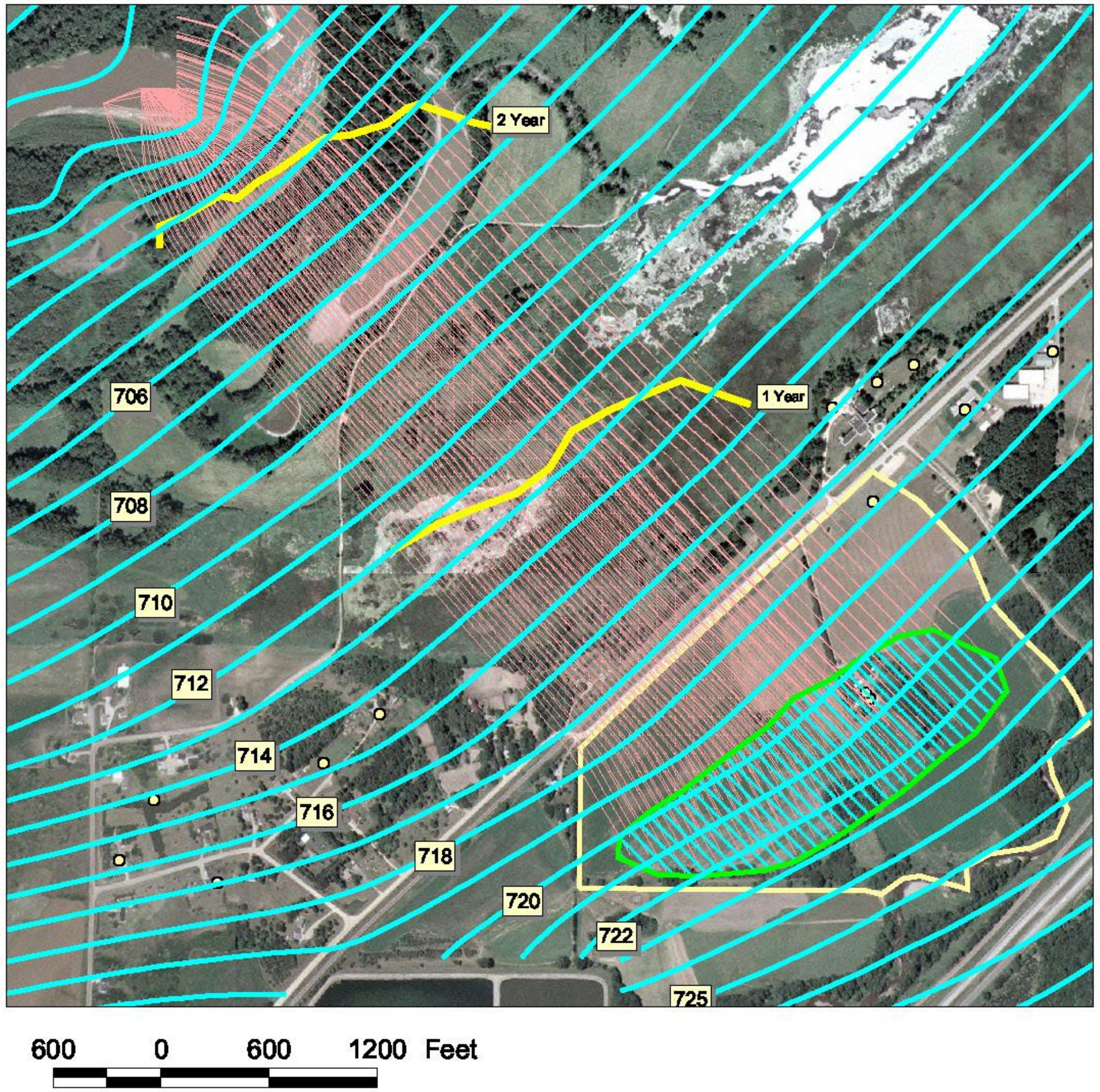
2. With the project in place (full pit extent and depth and project well not pumping), groundwater flow velocities are in the range of 1,620 to 2,750 feet per year. Four wells appear to be downgradient of the pit area: the Robling well; the SCALES well, the Wayne well, and the Schenck well. All of these wells are predicted to be within the one-year time-of-travel zone, assuming an effective porosity of 0.2 and an average hydraulic conductivity value of 287 ft/day.

3. Under flood conditions, the pit would likely be inundated with flood water that would migrate to the northwest into the aquifer after the flood recedes. Inundated flood waters are predicted to migrate to the SCALES well (northeast of the site) within 6 months to 1 year following a flood. Other wells that would receive diluted flood water include the Robling well (Unique No. unavailable) , the Wayne well (Unique No. unavailable), and possibly the Schenck well (70W0005585). Once impacted, these wells will continue to be affected by flood water for 2 to 3 years until the inundated flood water migrates further downgradient toward the Minnesota River. Other wells may be within the affected areas shown on Figure 2 of the Memorandum. Wells outside these affected areas will likely not be impacted by flood water inundation of the project.

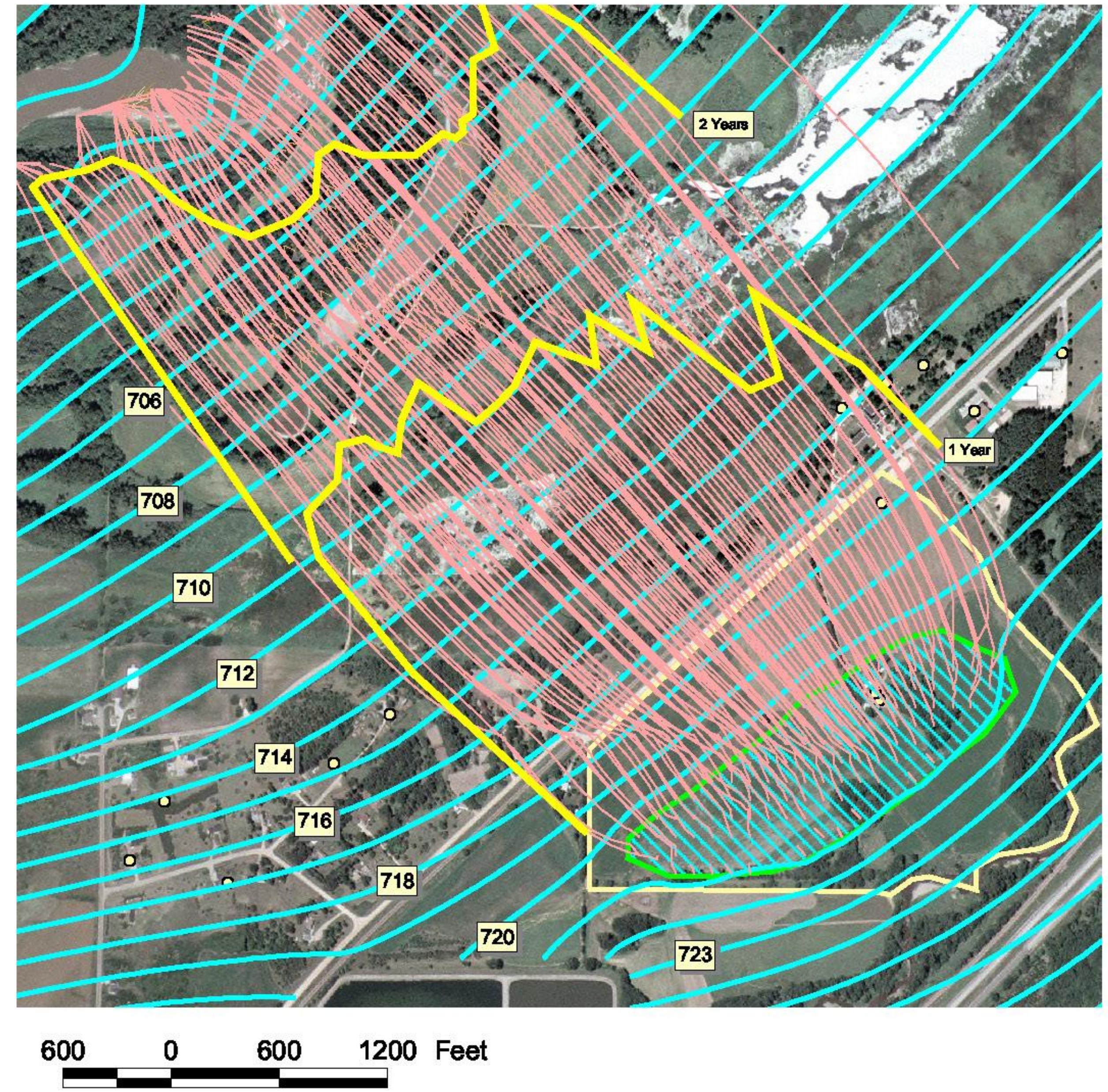
4. Water from the site is not predicted to migrate into the underlying bedrock under current conditions, steady-state operating conditions, or flood conditions. Groundwater flow in this area is upward from the Franconia into the overlying surficial deposits because this is a regional discharge zone for bedrock. If, in the future, a high-capacity well were installed near this area in the Franconia, pumping might cause a reversal in the vertical gradient.

5. The City of Jordan's current municipal wells and other municipal wells in the region will not be affected by this project.

There is always some uncertainty associated with the types of predictions presented above. Heterogeneity in the aquifer, errors in assumptions for unavailable parameters, and seasonal variations in flow conditions may result in actual conditions that differ slightly from the predicted conditions. For example, the Juvenile Alternative Facility well is located just outside of the area of flow from the mine pit but it is reasonable to include the Juvenile Alternative Facility well in the list of affected wells for the purpose of accounting for the predictive uncertainty of the modeling simulations. When using the results of the modeling, judgment should be exercised.



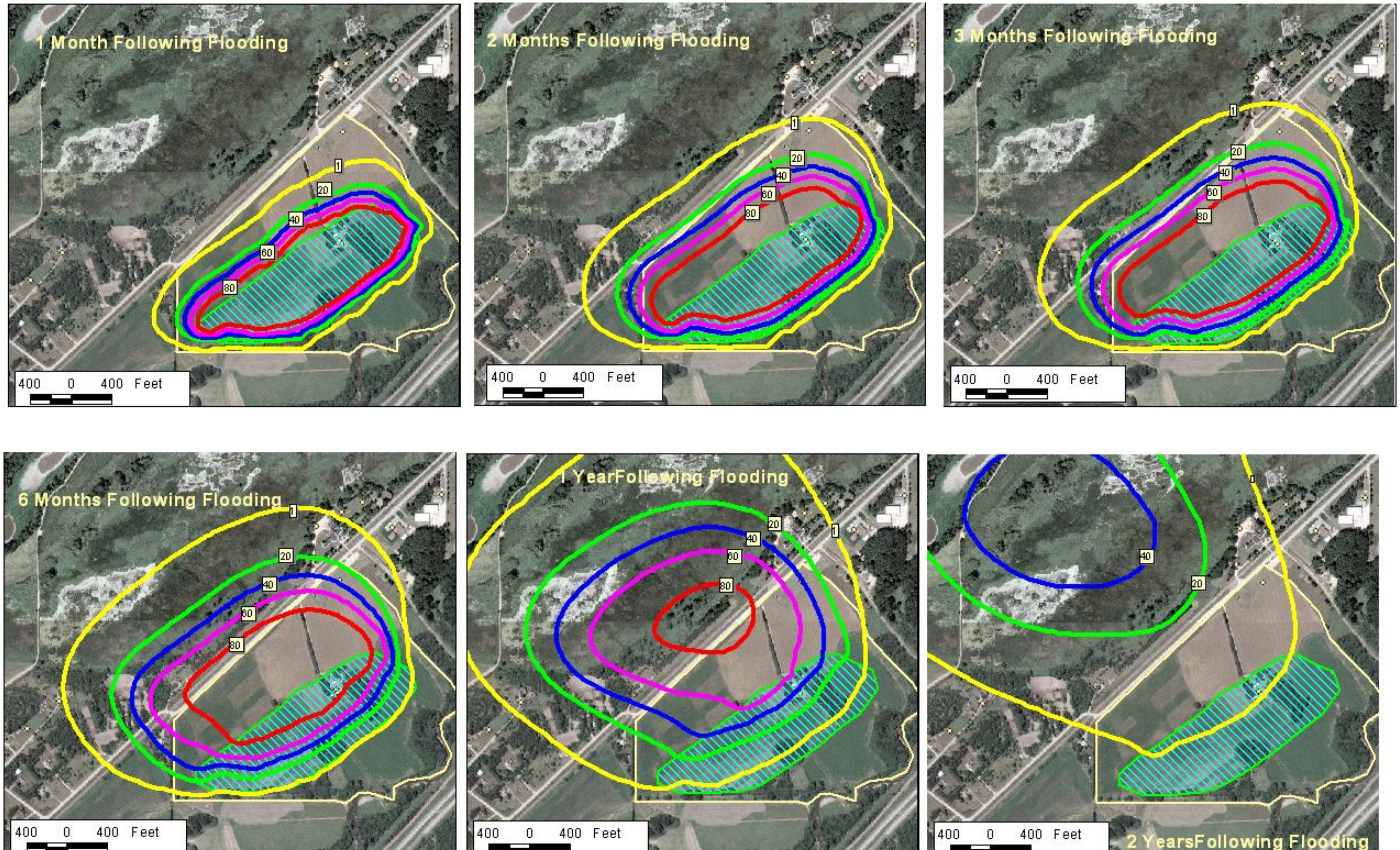
Model Prediction of Current Groundwater Flow Conditions, Direction, and Travel Time



Model Prediction of Groundwater Flow Conditions, Direction, and Travel Time with Pit
(mine production well NOT pumping)

Figure 1

Steady-State Simulations of Water-Table Elevations,
Groundwater Flow Paths, and
Groudnwater Time-of-Travel fro the Current
Condition and for the Mine Pit at Full Extent



Contours are a percentage of floodwater in pit (20% contour interval)

Figure 2 Simulation Results of Flood Water Migration Through Aquifer